



ngDIFMAP: new generation DIFMAP and applications in AGN morphology

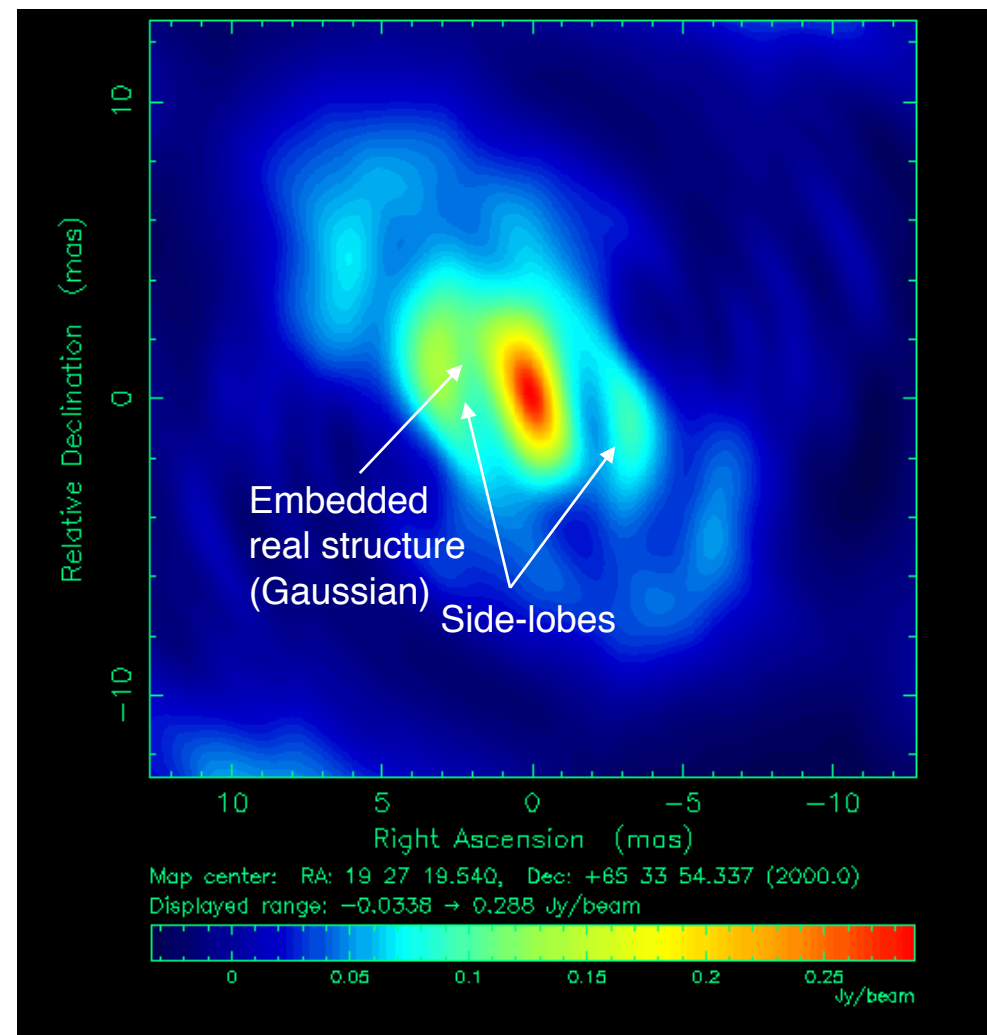
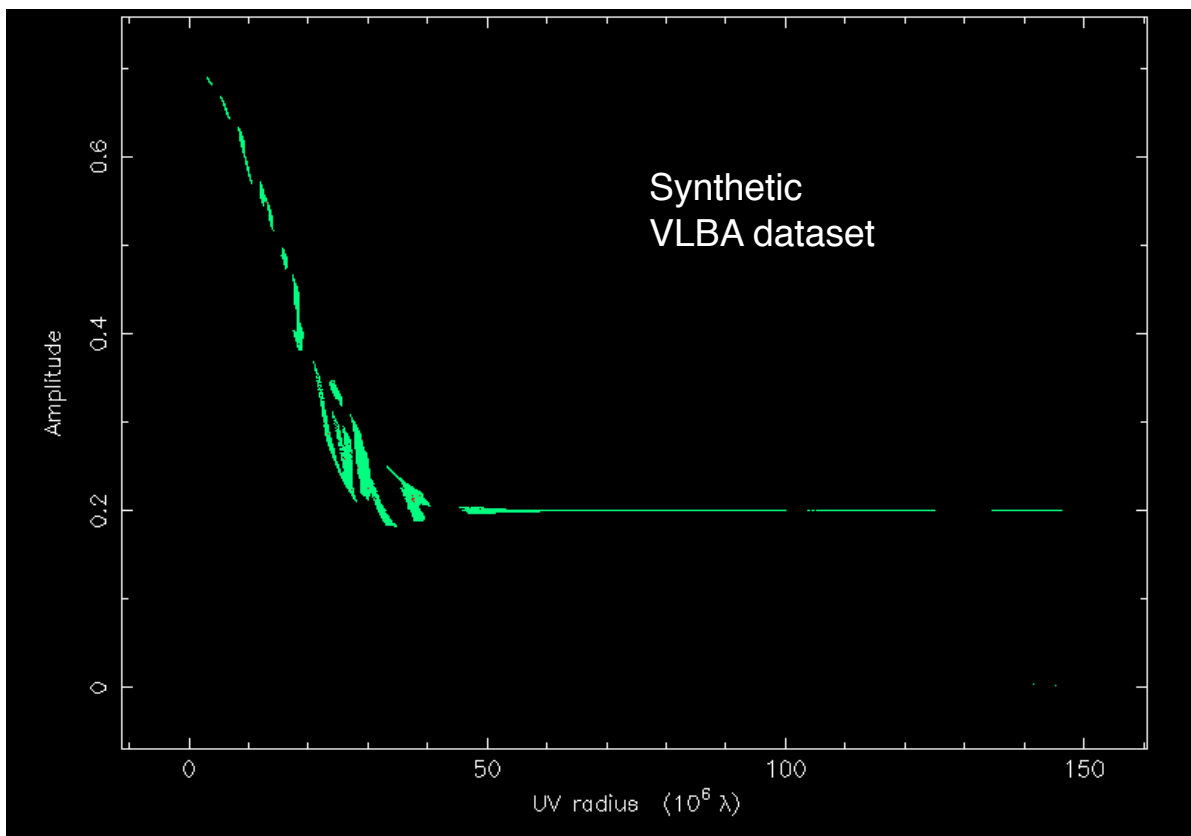
Agniva Roychowdhury, University of Maryland Baltimore County, USA.

EVN Symposium, UCC, Ireland, 15th July 2022

Co-authors: Eileen Meyer (PhD advisor), Markos Georganopoulos

Why DIFMAP (Shepherd M., Pearson T., Taylor G., 1994) :

Sparse U-V coverage



Why DIFMAP :

Interferometric gain errors

Antenna-specific gain True visibility
Baseline-specific gain Thermal noise

$$\tilde{V}_{ij} = H_{ij} G_i G_j^* [V_{ij} + \epsilon_{ij}]$$

Antenna-separable errors

$$\tilde{V}_{ij} = (1 + a_i)(1 + a_j)e^{i(\phi_i - \phi_j)} A_{ij} e^{i\Psi_{ij}} + \text{Bispec}$$

$$\tilde{\Psi}_{ijk}(t) = [\tilde{\Psi}_{ij} + \tilde{\Psi}_{jk} + \tilde{\Psi}_{ki}] = [\Psi_{ij} + \Psi_{jk} + \Psi_{ki}] + \text{Amp} + \text{CI Phase}$$

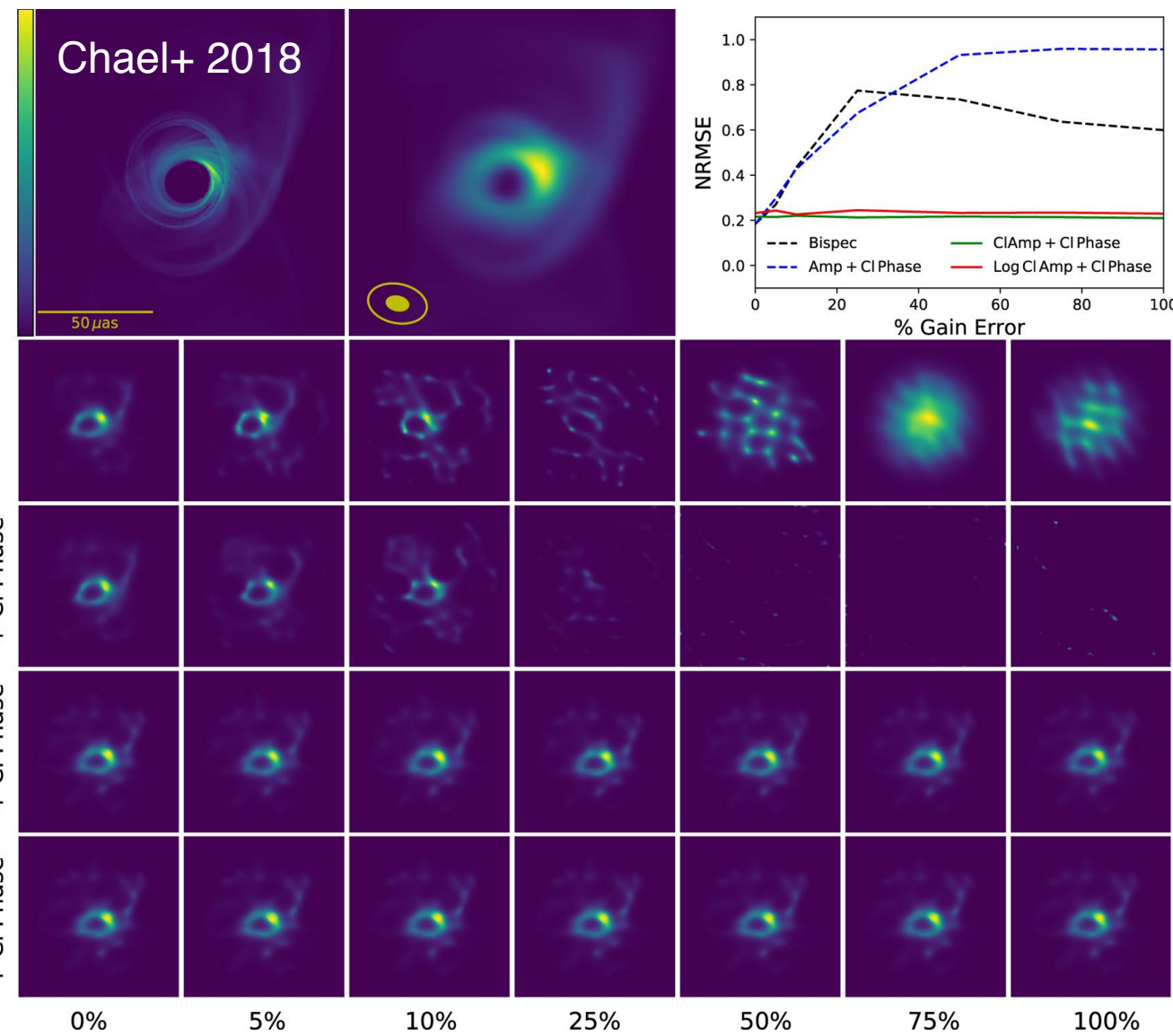
Closure phase

Closure amplitude

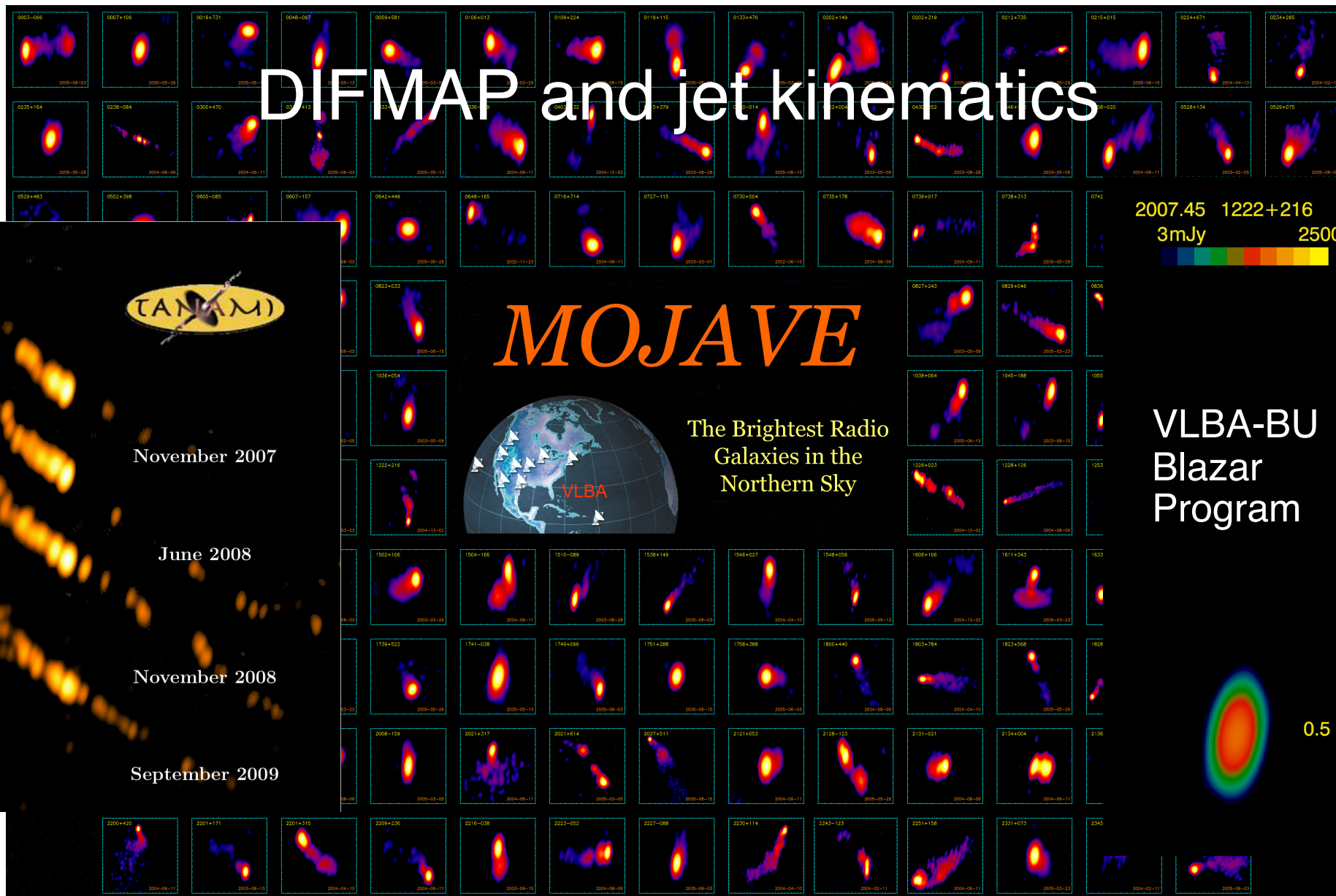
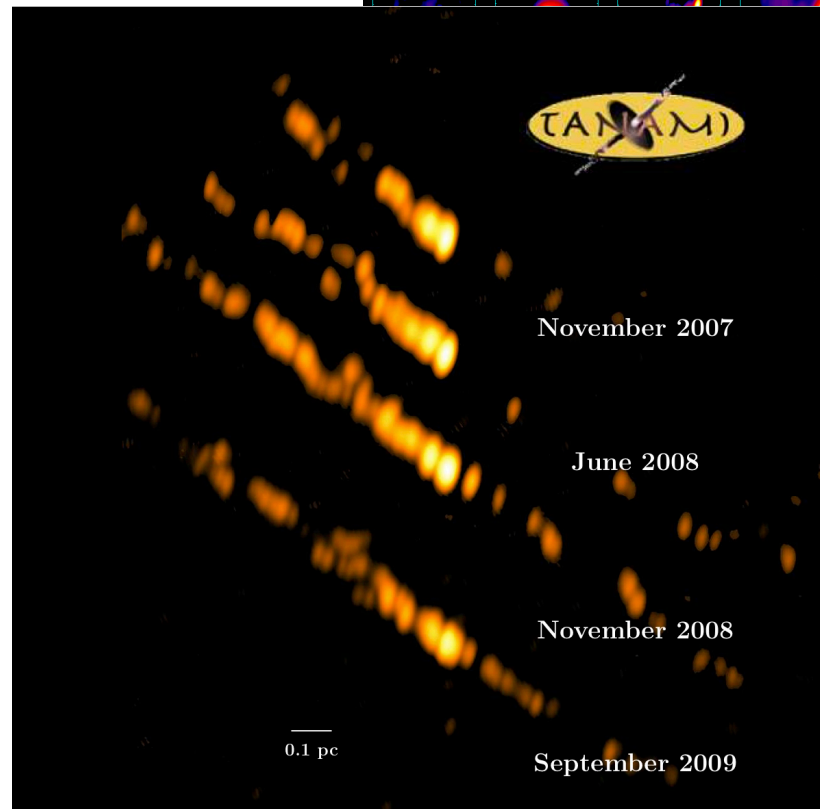
$$A_{ijkl} = \frac{|\tilde{V}_{ij}||\tilde{V}_{kl}|}{|\tilde{V}_{ik}||\tilde{V}_{jl}|} = \frac{|V_{ij}||V_{kl}|}{|V_{ik}||V_{jl}|}$$

Baseline-based, or "closure" errors (figure)

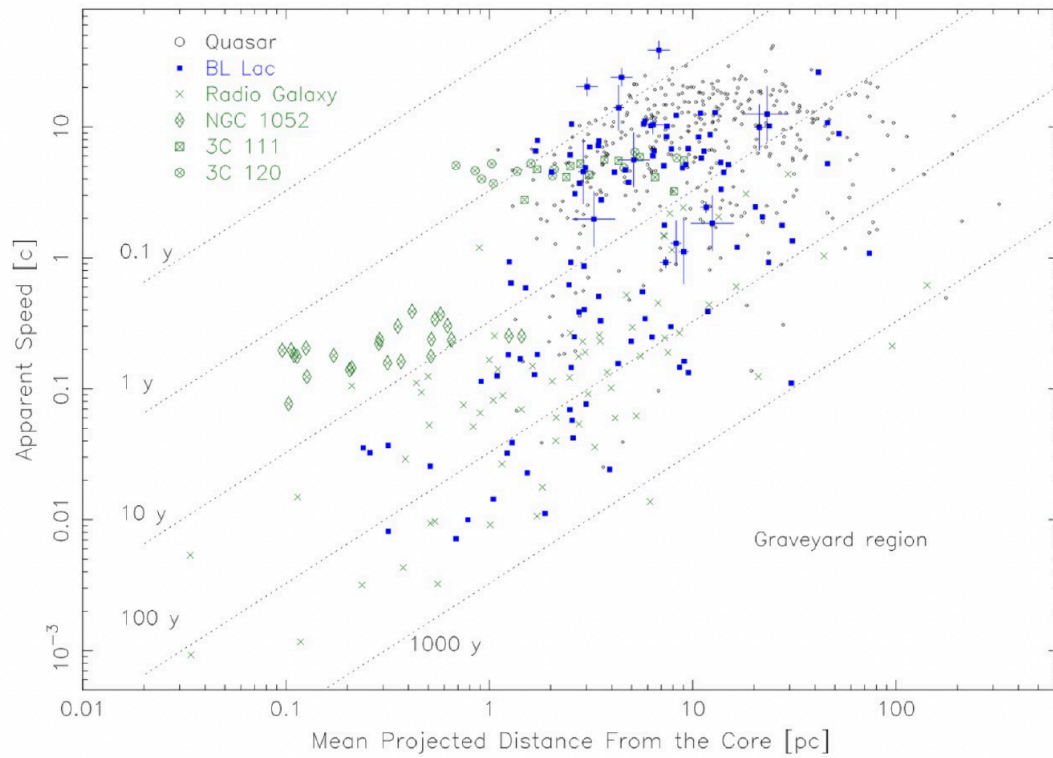
$$\tilde{V}_{ij} = [1 + Y_{ij}(t)]e^{j\delta\phi_{ij}} [V_{ij} +$$



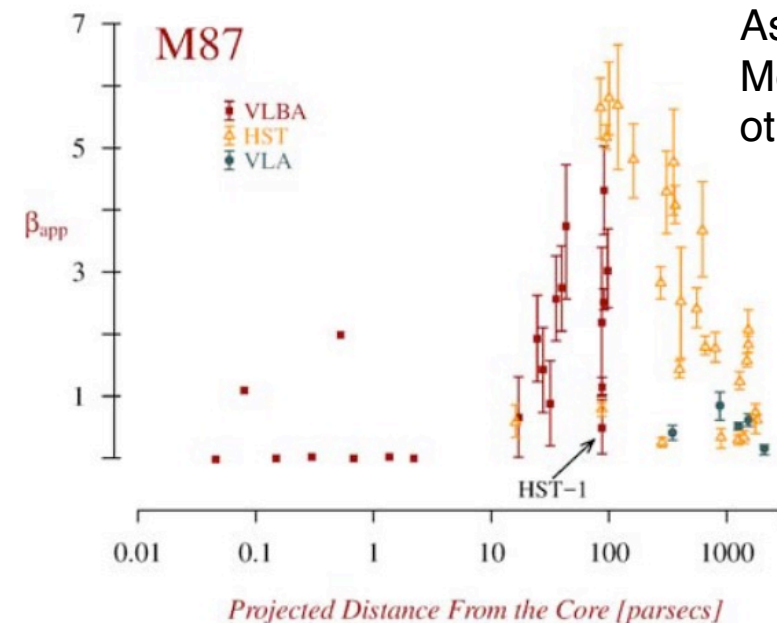
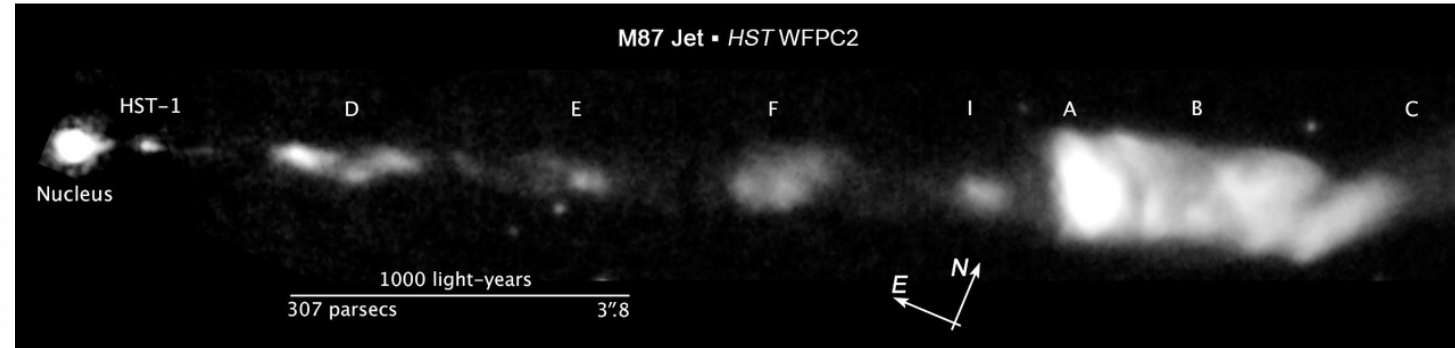
DIFMAP and jet kinematics



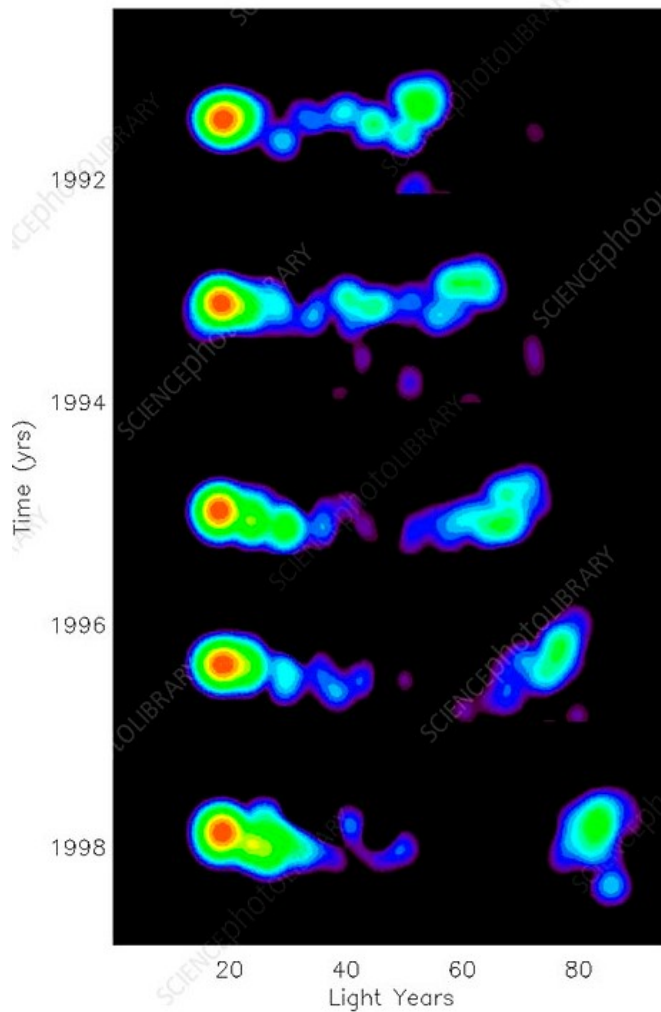
A “MOJAVE on the kpc-scale”?



Lister+ 2016



Asada+ 2014,
Meyer+ 2015 and
others



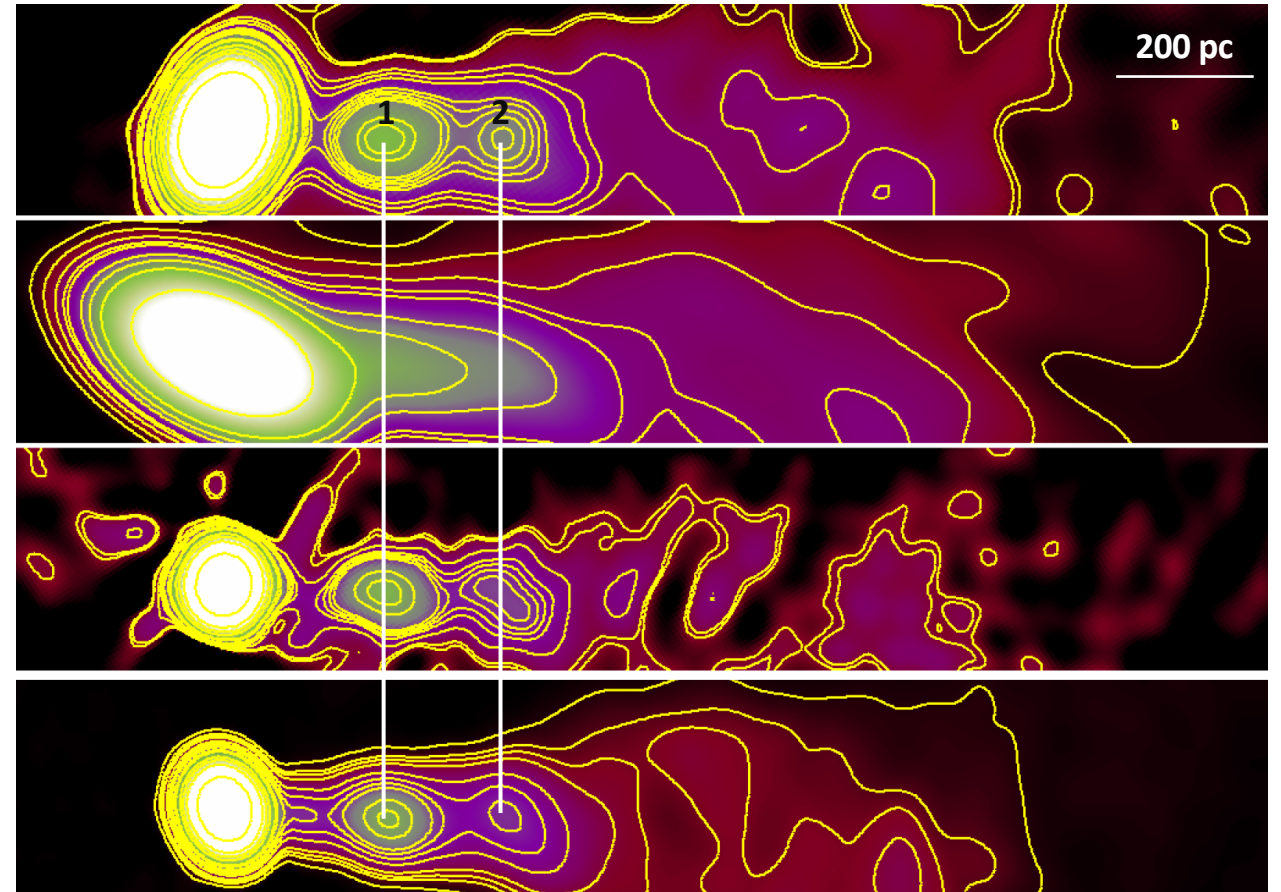
VLBI Jet of 3C 279
(Wehrle+ 2001)

1985, 15 GHz

2000, 8.4 GHz

2003, 22 GHz

2019, 22 GHz

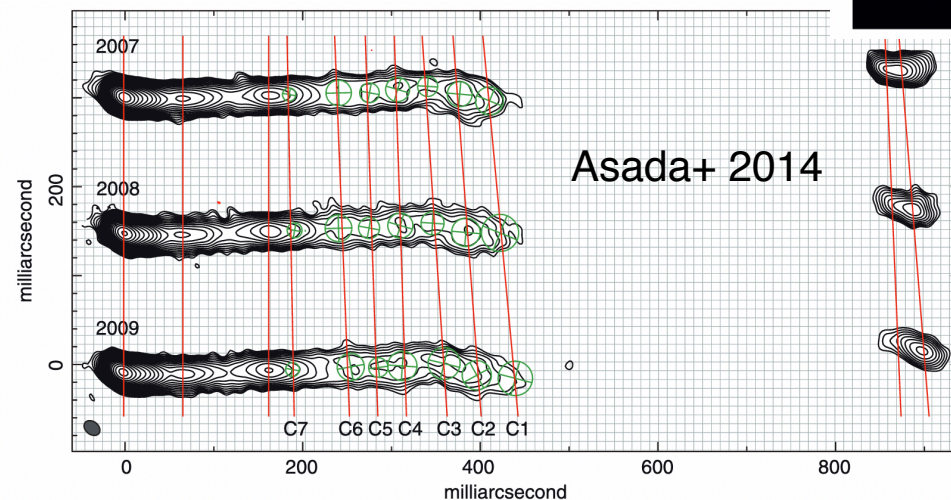
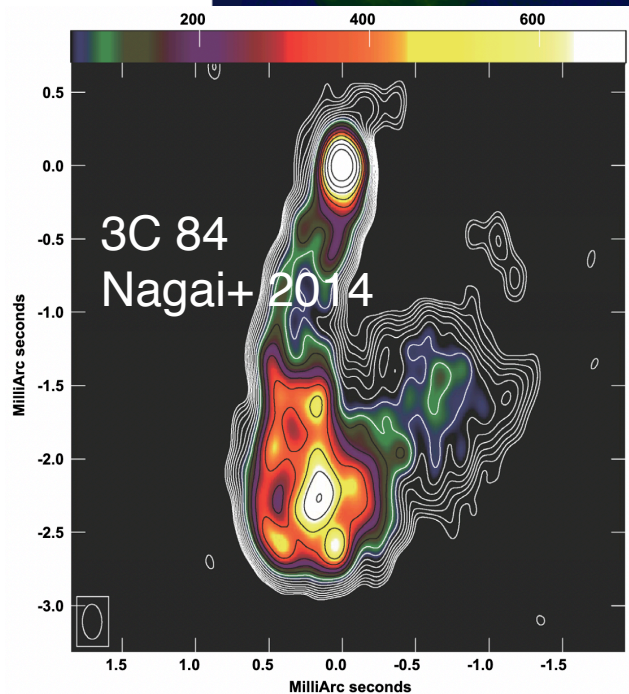
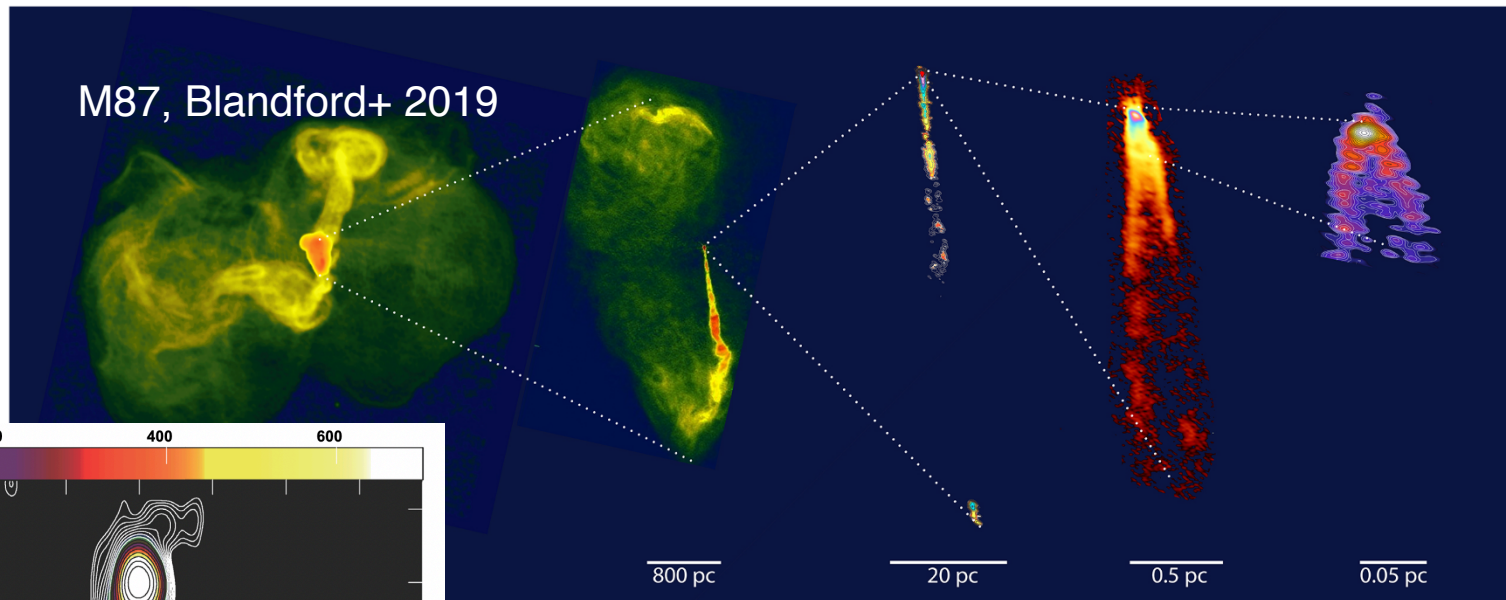


VLA jet of 3C 78

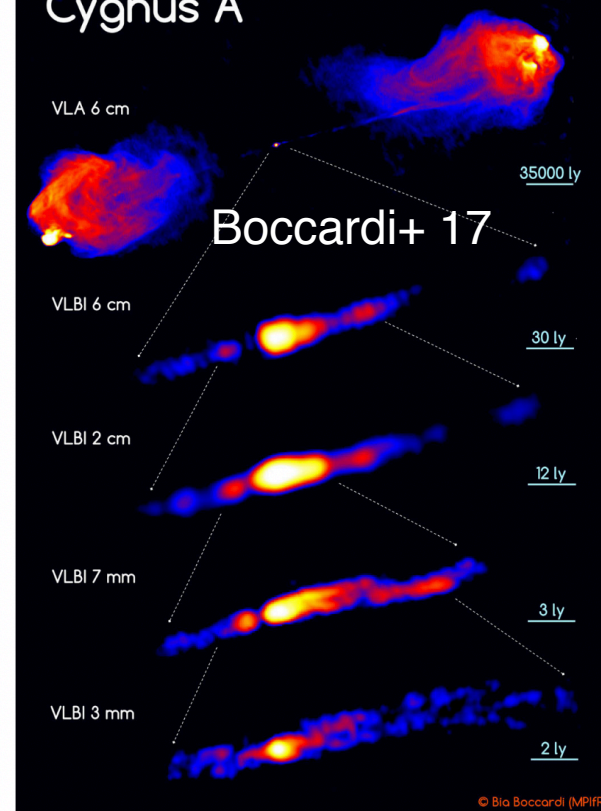
Need higher accuracy, and uncertainties need to be quantified.

Need for model complexity:

M87, Blandford+ 2019



Cygnus A



Introducing ngDIFMAP and capabilities

Better for large parameter space,
but time consuming

Global Optimization
Technique, Simulated
Annealing (Goffe+
1985)

Closure Quantity Fitting

Circumvents antenna-based gain
errors (function present in
obsolete Caltech VLBI programs)

DIFMAP

+

Monte Carlo simulations
of errors to compute
uncertainties in parameter
space.

Modifiability

=

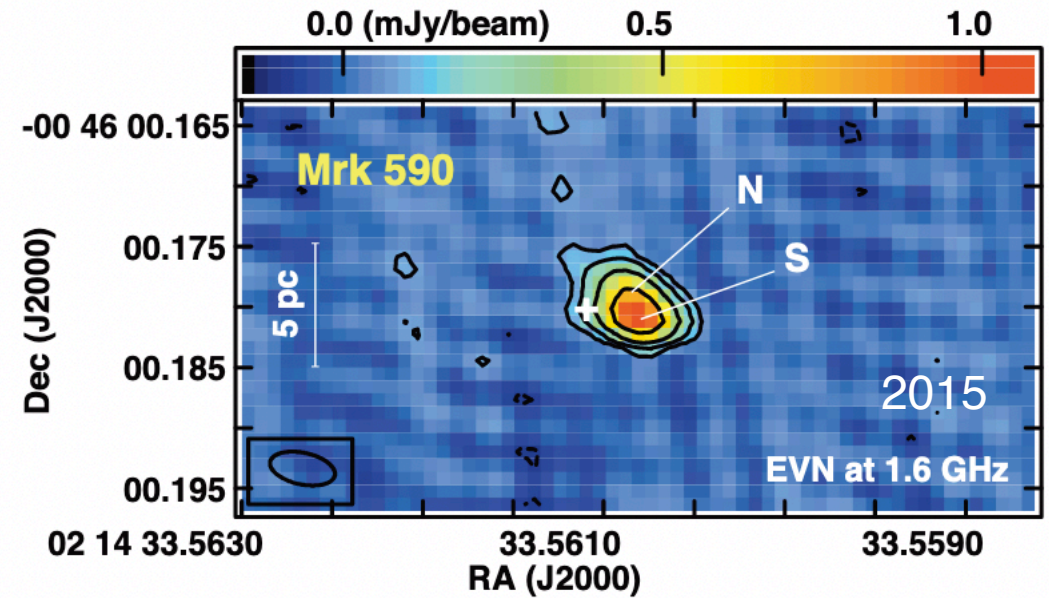
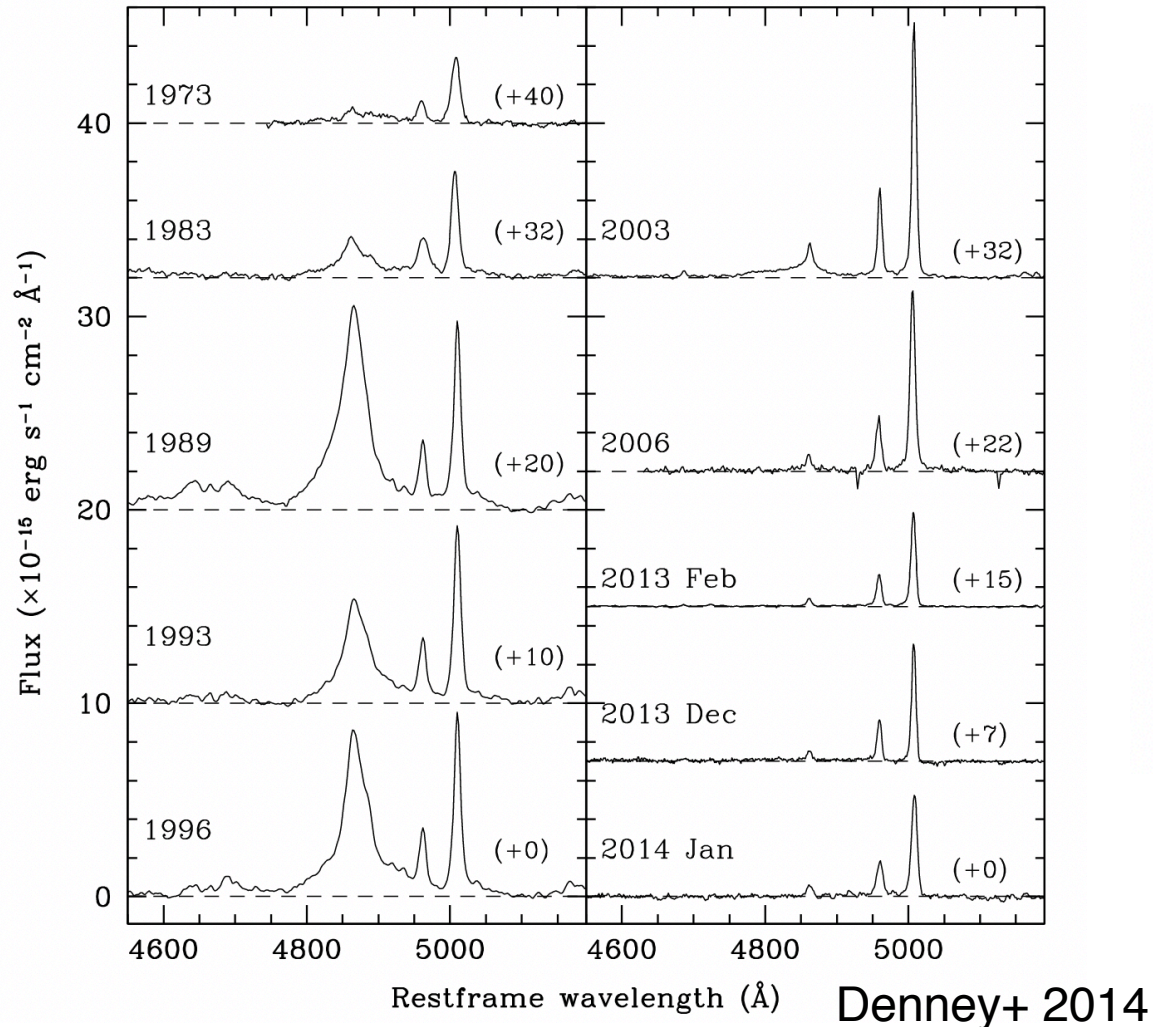
ngDIFMAP

Previous effort: DIFWRAP
(Lovell 2000) but not
fundamentally better than
DIFMAP's error estimation.

Example of simple previous
modification: Britzen S., ...,
Campbell R.M., et al. 2007,
A&A, 472, 763

Application (DIFMAP)

Radio emission from radio-quiet AGN: case of changing look Mrk 590



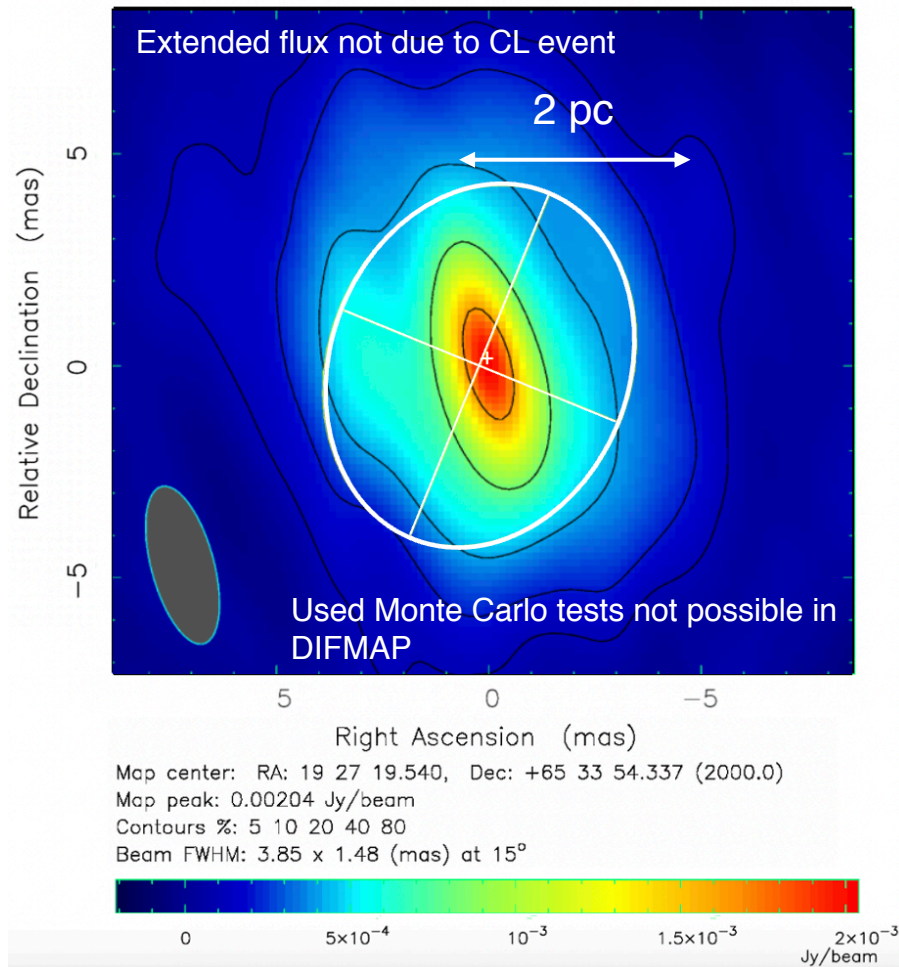
Possible nascent jet, Yang+ 2021

Software used: AIPS+DIFMAP

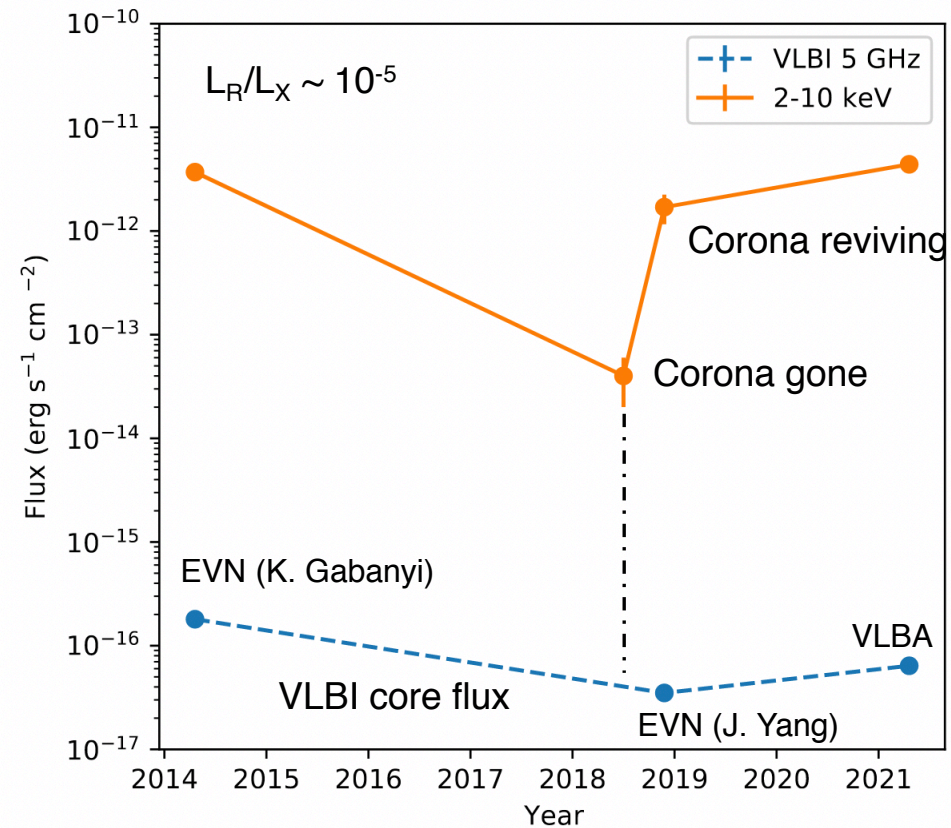
Application (ngDIFMAP)

Radio emission from radio-quiet AGN: case of changing look 1ES 1927+654

Clean I map. Array: BFHKLMNOPS
B1927+6527 at 4.980 GHz 2021 Mar 15



Appearance of broad lines around 2017-2018

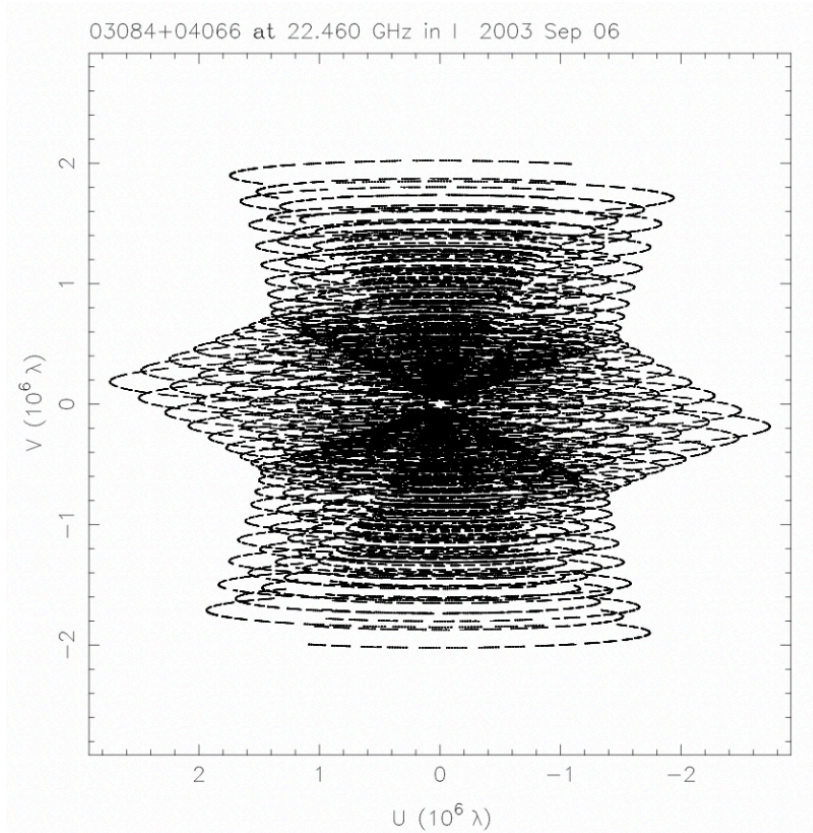


Near confirmation of coronal origin of radio emission (synchrotron). Has *never* been observed before.

arXiv: 2203.07446, Laha+, 2022, ApJ, 931,5

Software used: AIPS+ngDIFMAP

Determination of uncertainties in model-fitting



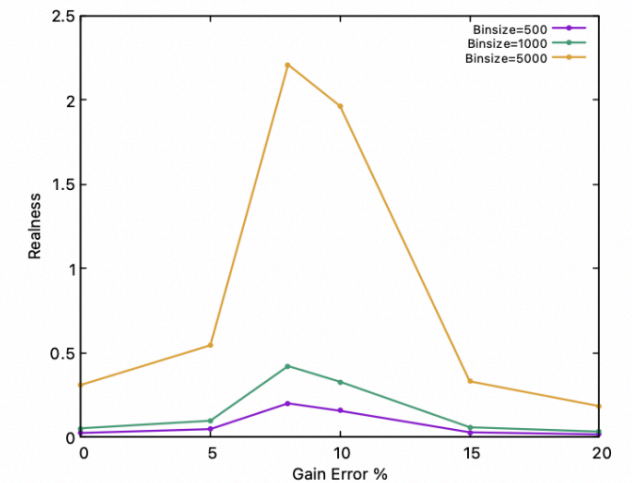
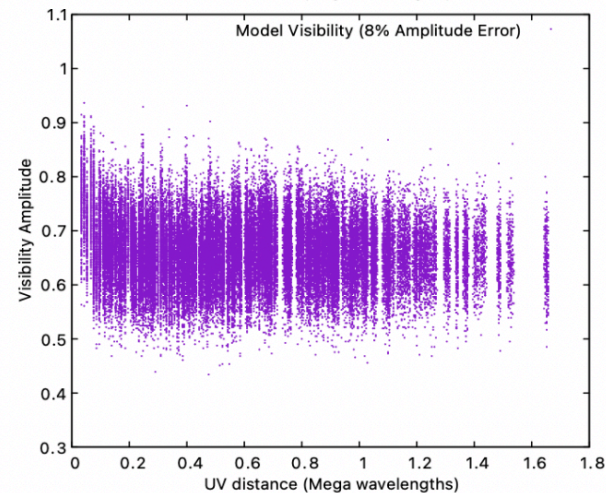
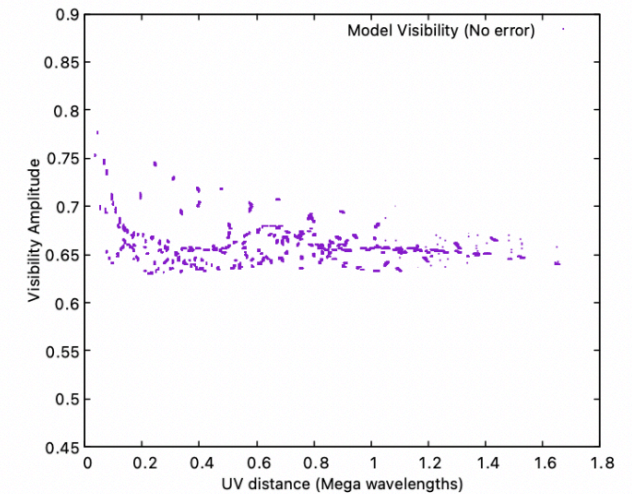
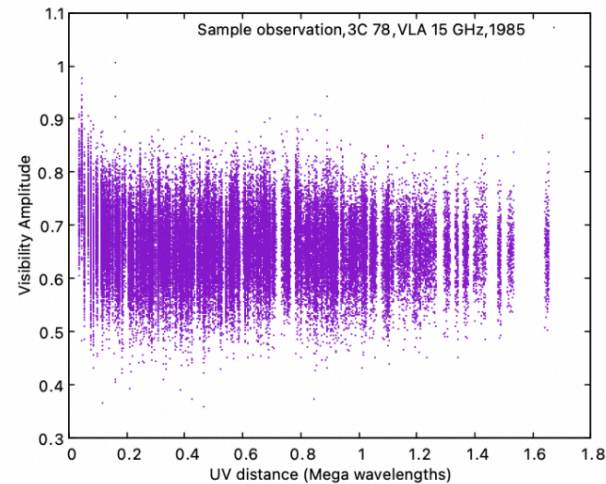
$$\tilde{V}_{ij} = [1 + Y_{ij}(t)] e^{j\delta\phi_{ij}} [V_{ij} + \epsilon_{ij}(t)]$$

$$Y_{ij} \sim \mathcal{N}(0, \sigma_g) \quad \delta\phi_{ij} \sim \mathcal{N}(0, \sigma_p)$$

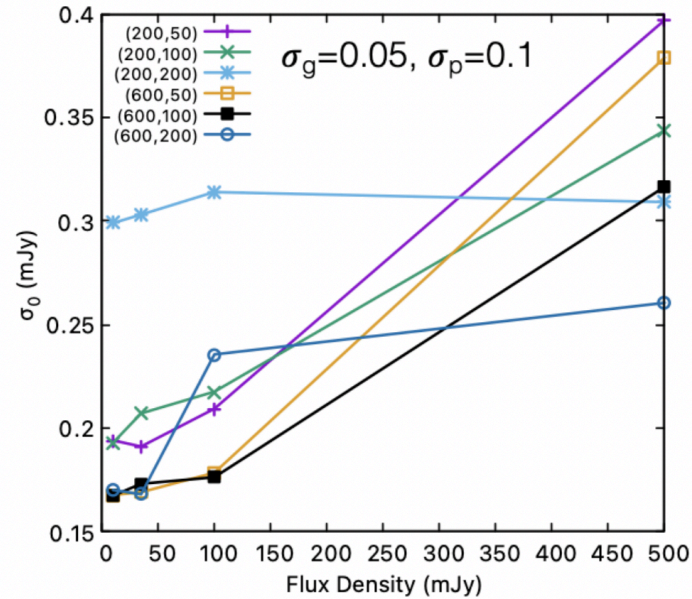
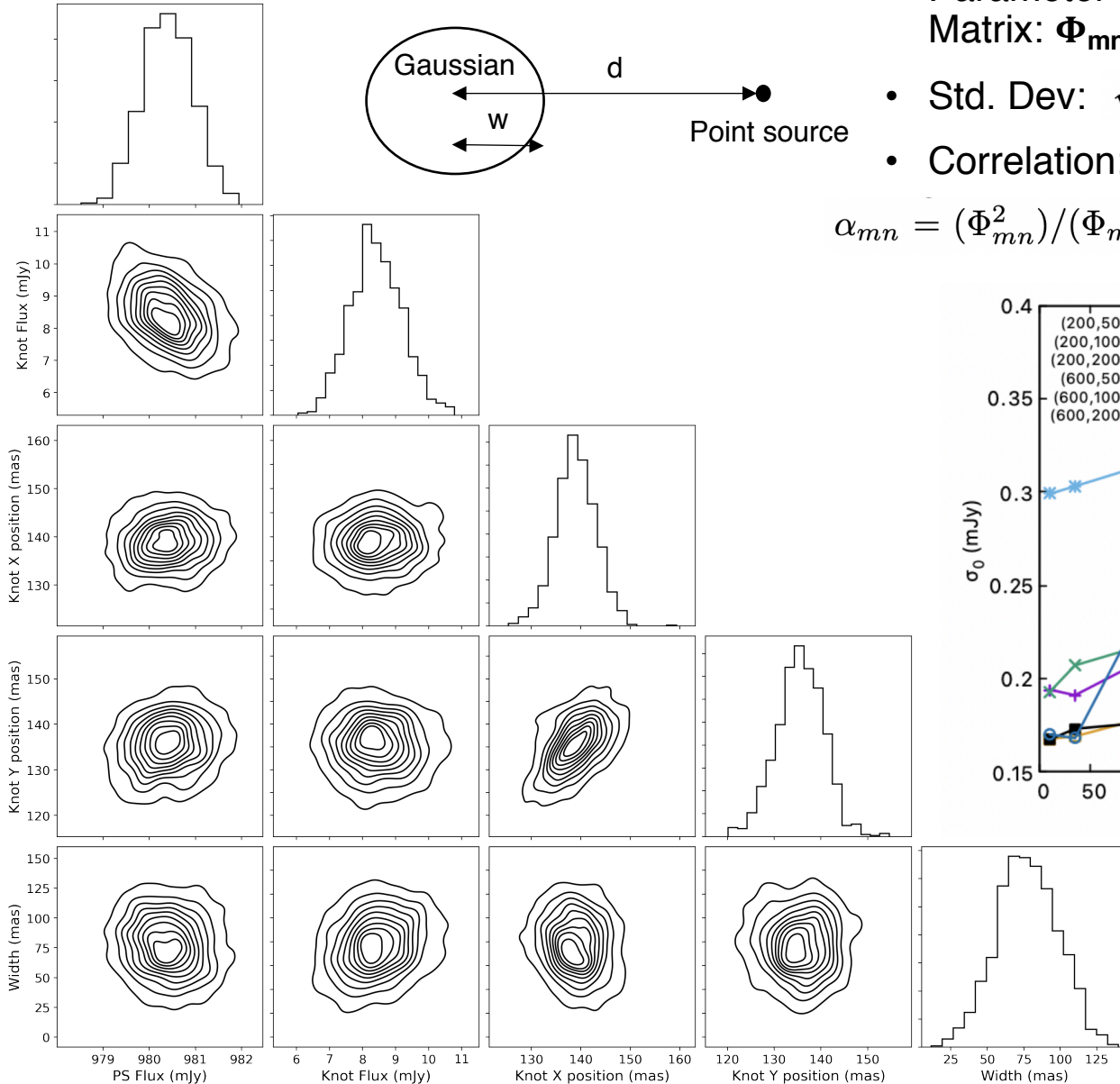
Starting best-fit model

Random loss in UV coverage and residual gain errors (Monte Carlo method)

Resulting parameter covariance matrix from *all* best-fit results, not single-fit matrix already in DIFMAP

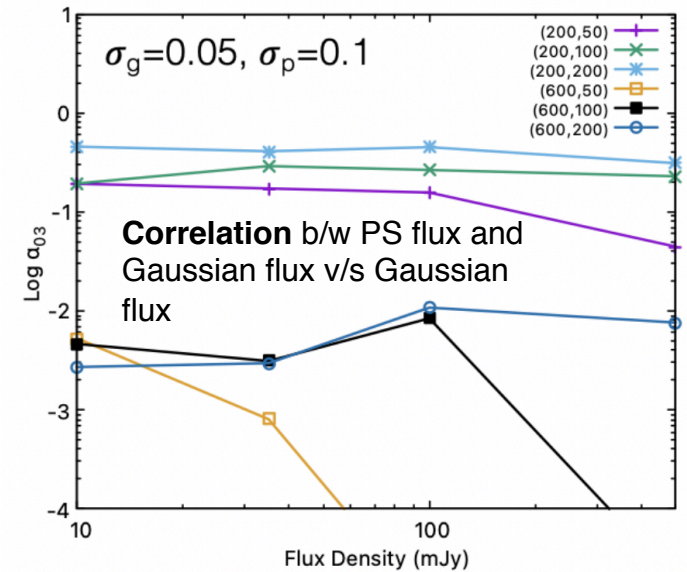
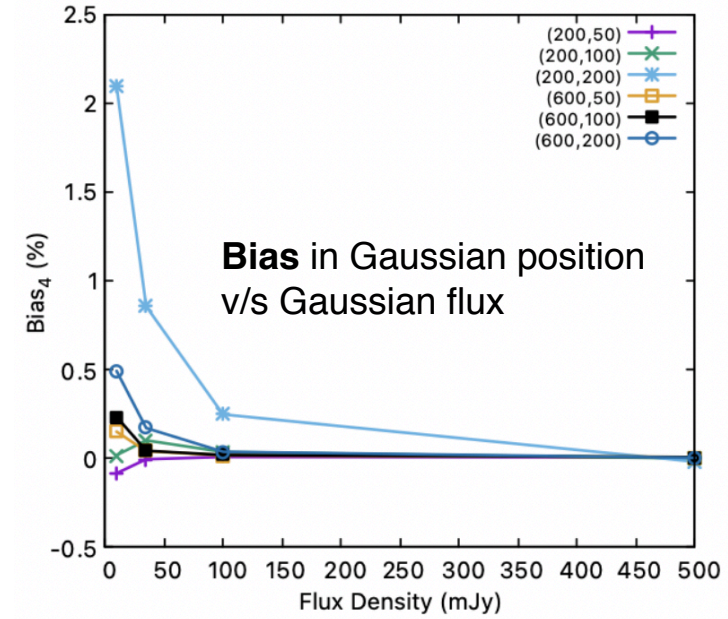


Starting test model and output plots:



Point source flux **std. dev.**
v/s Gaussian flux

Roychowdhury+ 2022a
(to be submitted)



Summary and conclusions

- Novel modification to DIFMAP to robustly understand noisy interferometric data.
- New models will be added and convolution engine will be improved (only Gaussians and PSs can be convolved in DIFMAP).
- Immense scope for further modification: possibilities include *rewriting* DIFMAP with MPI to handle latest large datasets.

Originally developed for CAGNVAS: *Catalogue of proper motions in extragalactic jets from Active galactic Nuclei with Very large Array Studies*.
(Vide talk at COSPAR (E1.2) next week.)

